PRTS

09/787819
JC0[illegible]c'd PCT/PTO 23 MAR 2001

Method and Device for Surface Treatment of Workpieces and Use thereof

The invention relates to a method and device for surface treatment of workpieces and use thereof for surface treatment of workpieces of metal, preferably of steel and/or aluminum and/or alloys thereof.

In drawing as well as in extruding workpieces such as. for example, elongated sections, of metal, more particularly of aluminum, an oxide film generally forms on the outer surface thereof of considerable thickness in part. In general in drawing or extruding workpieces of metal longitudinal cracks or the like materialize in the surface thereof, especially in the case of aluminum. Since such oxide films and such longitudinal cracks automatically result in in the strength of the workpieces being reduced subsequent cleaning or removal of the material surface is necessary. This is, however, highly labor-intensive and thus cost-intensive. In addition to this, workpieces produced by drawing or extruding generally feature dimensions having extremely large tolerance ranges and thus subsequent straightening or shaping otherwise of the workpieces produced by drawing or extruding is a mandatory requirement for further processing or further use. Such a step in operations likewise adds to the work or costs involved. Similar problems are involved in the surface treatment of workpieces incorporating bores or similar openings such as through-holes and/or blind holes.

The present invention is thus based on the object of providing a method and a device for surface treatment of workpieces, more particularly of elongated sections having any cross-section or workpieces incorporating bores or similar openings which is exceptionally simple and permits production of workpieces featuring particularly high strength and hardness as well as high accuracy with no

additional labor and cost expense as well as use thereof in surface treatment of workpieces, in the form of, for example, elongated sections of metal, more particularly of aluminum or alloys thereof.

This object is achieved by surprisingly simple ways and means as set forth in the features of claim 1.

The configuration in accordance with the invention of the method as set forth in the features of claim 1 in which the workpiece, for example, in the form of an elongated section, is worked at least in part by at least one roll provided at least in part with an outer profile such that the treated surface of the workpiece is exposed to inherent compressive stresses and the zones located beneath the treated surface of the workpiece is exposed to inherent tensiles stresses axially and tangentially, a particularly simple method is achieved for producing workpieces, such as elongated sections, or the bores and other openings thereof, e.g. through-holes and blind holes, at no high labor and cost expense with a substantially increased strength and/or hardness, extremely higher accuracy and smoothness. The method in accordance with the invention achieves cleaning the material surface and/or the zone near to the surface thereof of oxide crusts, for example, aluminum oxide crusts and detrimental soilage. During surface treatment surface defects are thus simultaneously eliminated to thus avoid crack propagation caused thereby. The result in all is that the workpieces are surrounded by an envelope several hundred microns thick identical in material which due to its enhanced material strength and the resulting inherent compressive stress has a stiffening effect. The surface roughness is improved as compared to that of the workpieces directly after drawing or extruding by a factor of roughly 6 to 8 better, whereby roughness values of ra < 0.1 are the rule. The workpieces receive by consequence an inherent stress characteristic, namely inherent compressive stresses

of the plastically deformed surface or near thereto and inherent tensiles stresses in the areas located beneath which act against each other. The workpieces receive consequently a considerably enhanced ultimate strength. As an additional advantage of the method in accordance with the invention due to a substantially reduced oxide film thickness an improved bonding is achieved with the result that the workpieces can be provided with galvaic coatings with no problem, i.e. without the usual hydrogen embrittlement. Due to the improved bonding all and any systems of corrosion protection are just as possible. Due to such a surface treatment a consolidated surface structure cleaned of porous oxide particles is attained. The result in all of this partial surface treatment is that the material receives an inherent stress system resulting in a considerable enhanced ultimate strength.

Advantageous design aspects of the method in accordance with the invention are described in the claims 2 to 18.

Of major significance for an additional simplification in surface treatment of the workpiece are the features as set forth in claim 2, by which the workpiece is moved in the axial direction by the at least one roll provided at least in part with an outer profile which eliminates the need for any separate means technically by the method for advancing the workpiece after surface treatment.

To further enhance the strength and hardness whilst improving the accuracy the workpiece in the special aspect of the invention as set forth in claim 3 is worked by at least one, more particularly two roll(s) provided at least in part with an outer profile in sequence in the opposite direction. In this way the surface of the workpiece to be treated is worked preferably transversely to the direction of movement of the workpiece first in one direction and then in the direction opposite thereto.

Of extreme significance for surface treatment of a workpiece having a round surface, for example, a round or tubular material, are the features of claim 4 by which the workpiece is worked by at least one roll provided at least in part with an outer profile arranged parallel to the workpiece and which is rotatable about the longitudinal centerline as well as about the workpiece.

Of great interest for surface treatment of a workpiece including at least one bore or similar opening or the bore or opening itself are the features as set forth in claim 5 by which the workpiece is worked by at least one roll provided at least in part with an outer profile arranged parallel to the bore or similar opening and which is rotatable about the longitudinal centerline as well as about the bore or similar opening.

It is further within the scope of the invention that the workpiece or its surface in the form of an outer-located surface area and/or an inner-located surface area, for example, the inner wall of a bore, as set forth in claim 6, is worked by a roll provided at least in part with an outer profile and at least one, more particularly substantially non-profiled roll(s) arranged about the workpiece or in the at least one bore or similar opening.

As set forth in claim 7 it is provided for in this context that the workpiece is worked by a roll having an outer profile in the form of annular beads and recesses arranged at an angle α and/or α« to the longitudinal centerline of the roll, whereby the annular beads and recesses arranged at an angle α and/or α« to the longitudinal centerline of the roll comprise a lead position substantially opposing each other.

In another aspect of the method in accordance with the invention as set forth in claim 8 the workpiece is worked by two rolls each provided at least in part with an outer profile and a substantially non-profiled roll arranged about the workpiece, more particularly equispaced from each other.

Preferably the workpiece or the surface area thereof to be treated is worked as set forth in claim 9 by two rolls having an outer profile in the form of annular beads and recesses arranged at an angle α or α' to the longitudinal centerlines of the rolls.

In this context the two rolls as set forth in claim 10 are preferably powered in the same direction of rotation when the annular beads and recesses arranged at an angle α or α' to the longitudinal centerlines of the two rolls comprise a lead position substantially opposing each other.

As an alternative thereto the rolls as set forth in claim 11 are powered in the opposite direction of rotation when the annular beads and recesses arranged at an angle α or α' to the longitudinal centerlines of the two rolls comprise a lead position substantially the same to each other.

In yet another aspect of the invention for surface treatment of a workpiece including at least one flat surface it is particularly of advantage as set forth in claim 12 that the workpiece is worked by at least one roll provided at least in part with an outer profile arranged substantially perpendicular or at an angle β to the workpiece and rotatable about the longitudinal centerline thereof.

Expediently the workpiece in accordance with the means as set forth in claim 13 is worked by at least one roll provided at least in part with an outer profile and is worked or supported by at least one further roll provided at least in part with an outer profile or a non-profiled roll

or similar supporting means located spaced away and opposite the at least one roll.

Yet another aspect of the method in accordance with the invention involves working the surface to be treated of the workpiece as set forth in 14 by the at least one roll including an outer profile in the form of annular beads and recesses.

It is furthermore within the scope of the invention to work the surface of the workpiece to be treated as set forth in claim 15 by several rolls having an outer profile in the form of annular beads and recesses, whereby the annular beads and recesses of adjoining rolls differ from each other in their configuration and arrangement and/or each of the adjoining rolls is powered in a different direction of rotation.

In this arrangement as set forth in claim 16 it is provided for in accordance with the invention that the workpiece or the surface area of the workpiece to be treated is worked by rolls having an outer profile in the form of beads and recesses arranged at an angle α or α' to the longitudinal centerlines of the rolls, whereby the rolls are powered in the same direction of rotation for a substantially opposite lead position of the beads and recesses or in the opposite direction of rotation for a substantially same lead position of the beads and recesses.

As an alternative or in addition thereto it is provided for in accordance with the invention that the workpiece or the surface area of the workpiece to be treated as set forth in claim 17 is worked by rolls having an outer profile in the form of annular beads and recesses arranged perpendicular to their longitudinal centerline, more particularly axially staggered relatively to each other.

Of particularly great significance are in conclusion the features as set forth in claim 18 by which the workpiece to be treated or the surface to be treated at least in part or the at least one bore or similar opening to be treated of the workpiece is coated with a covering of metal, such as chromium, copper or the like, and/or with a metal alloy and/or a paint and/or plastics and/or is anodized and/or galvanized and/or pickled. By means of the invention considerably improved bonding properties of the treated workpieces are achievable. This in turn produces quite generally substantial improvements as regards coating the workpieces, it thus being possible, for example, to coat a elongated section, such as a wire, having a core of aluminum with a (closed or continuous) shell of copper. The copper coating remains bonded to the core of aluminum extremely durably and particularly resistant to abrasion. Making use of copper wires of solid material is now no longer necessary. In addition to weight-savings this thus achieves particularly considerable cost-savings. Likewise possible by the method in accordance with the invention are high-load hard chromium coatings or the like without cost-intensive preparatory work, it now being possible, for example, to totally eliminate complicated and time-intensive stripping of the near-surface oxide films and/or soilage prior to chromium-plating workpieces such as brass shafts and the like, as hitherto necessary. Now likewise possible is a coating resistant to abrasion of, for example, anodizing paints or anodizing or galvanizing of workpieces.

In this arrangement, depending on the material properties or specifications to be achieved in each case, the workpieces to be treated or the treated workpieces and/or their coatings may consist of base metals such as for example, aluminum, lead, chromium, iron, cobalt, nickel, copper, manganese, molybdenum, silicon, tungsten, tin. zink or alloys thereof such as brass or of noble metals such as gold, palladium, platinum, silver or alloys thereof, or of

combinations of base and noble metals. Preferred are steel and/or aluminum and/or alloyed aluminum such as for example, $AlMg_{4.5}Mn$, $AlMgSi_{0.5}$, AlMgSi, $AlMg_5$, $AlZn_{4.5}Mg$, AlCuMg, $AlCuMg_2$, $AlZnMgCu_{0.5}$, $AlZnMgCu_{1.5}$, AlCuMgPb.

This object is achieved by surprisingly simple means by a device having the features as set forth in claim 19.

In accordance therewith the device in accordance with the invention for the surface treatment of workpieces, for example, of elongated sections, having a round surface, comprises three rolls arranged parallel to and about the workpiece, more particularly equispaced from each other, provided at least in part with an outer profile working the surface of the workpiece and each rotatable about their longitudinal centerlines as well as in conclusion about the workpiece. The device in accordance with the invention is thus characterized by a particularly simple and compact design. In addition the device in accordance with the invention assures a extremely high production accuracy in the production of workpieces have especially high strength and hardness as well as with high accuracy. Thus, workpieces, for example, in the form of elongated sections, can be produced with accuracy of for example, up to at least approximately 1/10 mm. In addition the device in accordance with the invention subjects the workpieces, for example, in the form of elongated sections, to a surface treatment involving no rotary movement, thus enabling feed speeds of up to approximately 100 mpm, for example, to be attained for such workpieces having a round surface. Last but not least, it is due to an extremely high working speed that the device in accordance with the invention achieves a substantial reduction in the labor and costs involved in the surface treatment of such workpieces having a round surface.

This object is further achieved as regards the device by surprisingly simple features as set forth in claim 20.

In accordance therewith a device for surface treatment is provided suitable for correspondingly working workpieces or their bores or similar openings such a through-holes and/or blind holes just as well, more particularly for implementing the method as set forth in any of the preceding claims, comprising at least two, more particularly three rolls arranged in parallel and in the bore or similar opening which are provided at least in part with an outer profile working the bore or similar opening and each rotatable individually about their longitudinal centerlines as well as in combination in the bore or similar opening. In addition to the advantages as cited above it is just as possible in this way to fixedly clamp in place the workpieces to be surface treated, where necessary.

Advantageous design details of the device in accordance with the invention are described in the claims 21 to 37.

Of major importance for surface treatment of workpieces are the features of claims 21 and 22 by which a roll, more particularly two rolls is/are provided at least in part with an outer profile working the workpiece and the remaining rolls, more particularly one roll, are/is configured non-profiled.

As set forth in claim 23 the outer profile of the at least one roll working the workpiece or its surface and/or bores is configured in the form of annular beads and recesses arranged at an angle α and/or α' to the longitudinal centerline of the roll.

Due to the features of claims 24 to 26 it is possible to advantage to work the surface of the workpiece by the outer profile of the at least one, more particularly two rolls in sequence in the opposite direction, i.e. by dual shaping

substantially approximately transversely to or also inclined to the direction of movement of the workpiece.

It is furthermore within the scope of the invention to provide the at least one roll as set forth in claim 27 with non-profiled ends.

In this arrangement the non-profiled end of the at least one roll as set forth in claim 28 incoming in the direction of movement of the workpiece comprises a slightly smaller outer diameter to compensate any irregularities of the workpiece or to undertake a certain straightening function.

In accordance with the features of claim 29 the non-profiled end of the at least one roll outgoing in the direction of movement of the workpiece has by contrast a slightly larger outer diameter to bring the already surface treatment workpiece to a constant dimension with a smooth surface.

It is furthermore within the scope of the invention that the rolls as set forth in claims 30 and 31 are mounted by a drive means for rotating each of the rolls individually about their longitudinal centerlines and a drive head for rotating the rolls in combination about the workpiece.

The means afforded by claim 32, namely of controlling the drive means and/or the drive head hydraulically or pneumatically permit infinitely variable control in avoiding all and any slip and thus as a result an extremely high surface smoothness of the workpiece. This also permits extremely precise influencing the feed rate of the workpiece in taking into account the characteristical features and operating conditions, such as diameter of the rolls, pitch of the annular beads and recesses, workpiece diameter and many other things.

In this context powering the rolls and a worm drive of the drive head as set forth in claims 33 and 34 is expediently undertaken via separate drive motors which are especially suitable for hydraulic or pneumatic control. This aspect additional promotes precise control of the device in accordance with the invention so that the movement of the rolls and worm drive can be influenced individually in each case.

One such hydraulically or pneumatically acting drive means is supported to advantage in addition by a sealing arrangement as is described for example, in DE 196 10 809 A1. This sealing arrangement permits not only rotation of the rolls themselves but also rotation of the rolls about the workpiece.

The features of claims 35 and 36 serve in a further aspect of the invention an extremely high versatility of the device since due to the movement of the drive means and drive head relative to each other a lengthwise compensation of rolls differing in length and thus optional interchangeability of the rolls is made possible.

Achieving an extremely high accuracy or only very small tolerances whilst permitting a high feed rate is further the object of the features of claim 37, by which the drive means and/or the drive head is/are provided with a centering means for the workpiece to thus eliminate or at least reduce any vibrations occurring due to the surface treatment in the region of the rolls.

This object is achieved surprisingly simple by the device features as set forth in claim 38.

In accordance therewith the device in accordance with the invention for surface treatment of workpieces, preferably with elongated sections having at least one flat surface,

comprises at least one roll arranged substantially perpendicular or at an angle β to the longitudinal direction of the workpiece which is provided with an outer profile working the surface of the workpiece at least in part and which is rotatable about the longitudinal centerline thereof. The device in accordance with the invention is thus suitable particularly for surface treatment of workpieces having an approximately rectangular, for example square, cross-section. The advantages achievable with such a device are substantially identical to the advantages as cited above in conjunction with the embodiment of a device for surface treatment of workpieces having a round surface, such as simple design, production of workpieces with particularly high strength and hardness as well as high accuracy, low labor and cost expense, etc.

Expediently, the at least one roll provided with an outer profile at least in part as set forth in claim 39 is assigned at least one further roll provided at least in part with an outer profile or non-profiled roll or the same supporting means opposite to provide a so-called counter-bearing for the at least one roll. If not only the upper surface of the workpiece is to be treated by the at least one roll, but also the lower surface at the same time, at least one further roll is provided comprising an outer profile. Otherwise a non-profiled roll or similar supporting means, for example, in the form of a supporting plate etc may be employed.

Of major importance for the surface treatment are the features of claims 40 to 42 by namely the at least one roll comprising an outer profile having the form of annular beads and recesses at an angle α or α' to the longitudinal centerline of the roll in each case.

To further enhance the strength and hardness whilst improving the accuracy the aspects as set forth in claim 43

are of extremely high importance. In accordance therewith the at least one roll provided with an outer profile at least in part is followed by an additional roll provided likewise at least in part with an outer profile to work the surface of the workpiece in the direction of movement of the workpiece in sequence in the opposite direction, i.e. in shaping it approximately transversely or inclined to the direction of movement of workpiece in a single reciprocating movement.

Such a more or less reciprocating shaping of the surface of the workpiece is achievable to advantage by the features of claims 44 and 45 as a function of design configuration, arrangement and direction of rotation of the beads and recesses of the outer profile.

It is within the scope of the invention to provide upstream and/or downstream of the at least one roll provided at least in part with an outer profile working the surface of the workpiece as set forth in claim 46 at least one non-profiled roll in the direction of movement of the workpiece.

In accordance with the aspect of the device in accordance with the invention as set forth in claim 47 the at least one upstream non-profiled roll comprises a slightly smaller outer diameter to feed the workpiece evenly to the outer profile and to thereby compensate or at least to mitigate any existing irregularities and undesirable out-of-tolerance, the one upstream non-profiled roll thus serving a certain straightening function.

To bring the workpiece coming from the region of the outer profile to a predefined constant dimension with a smooth surface, the at least one non-profiled downstream roll as set forth in claim 48 comprises a slightly larger outer diameter. The at least one downstream, non-profiled roll can thus be put to use for additional shaping.

It is furthermore within the scope of the invention that the annular beads as set forth in claim 49 protrude beyond the outer diameter of the at least one roll.

The features of claims 50 to 52 serve surface treatment of workpieces of optional thickness, as compared to which the at least one roll is mounted in a mounting means movable relative to supporting means supporting the workpiece, for example, in the form of at least one further roll. The versatility of the device in accordance with the invention is enhanced thereby since workpieces of optional thickness and height dimension can be surface treated.

As set forth in claim 53 the mounting means and/or the supporting means is/are expediently hydraulically or pneumatically controllable.

By the features of claim 54, the at least one (further) roll is assigned in each case a separate drive motor in expediently achieving individual control of each roll.

It is furthermore within the scope of the invention that the rolls as set forth in claim 55 are configured multi-part, they more particularly for example, being composed of a roll of high toughness and an envelope of high strength or hardness and thus hardwearing.

In a further aspect of the invention the rolls as set forth in claim 56 are coolable by an internal cooling system and/or an external cooling bath as a result of which the useful life of the device can be enhanced.

By means of the method and the corresponding devices in accordance with the invention it is in conclusion as set forth in claim 57 further possible to produce workpieces of metal, more particularly base metals such as for example,

aluminum, lead, chromium, iron, cobalt, nickel, copper, manganese, molybdenum, silicon, tungsten, tin. zink or alloys thereof such as brass or of noble metals such as gold, palladium, platinum, silver or alloys thereof, or of combinations of base and noble metals. Preferred are steel and/or aluminum and/or alloyed aluminum such as for example, $AlMg_{4.5}Mn$, $AlMgSi_{0.5}$, AlMgSi, $AlMg_5$, $AlZn_{4.5}Mg$, AlCuMg, $AlCuMg_2$, $AlZnMgCu_{0.5}$, $AlZnMgCu_{1.5}$, AlCuMgPb or of noble metals such as gold, palladium, platinum, silver or alloys thereof, or of combinations of base and noble metals. Workpieces of for example, aluminum or alloys thereof have proven to be particularly suitable due to their various advantageous properties such as corrosion-resistance, low specific density, etc. It is particularly in the field of automotive engineering that these materials are finding ever-increasing application. The disadvantages associated with these materials such as for example, hitherto inadequate strength, labor- and cost-intensive pre- and after-treatment of the material surface due to existing oxide films and (longitudinal) cracks as well as extremely large tolerances etc can now be eliminated by the method and the associated devices in accordance with the invention by extremely simple ways and means.

Thus elongated sections of solid material, especially where hardened and/or coated, more particularly wires, rods and elongated and/or tubular material, more particularly tubing, preferably headrest brackets in automobiles can now be produced as set forth in claim 58.

As set forth in claim 59 the method and the device in accordance with the invention can also be put to use in the production of coiled, more particularly hardened and/or coated workpieces preferably coiled springs.

Expediently the method and the device in accordance with the invention are suitable as set forth in claim 58 likewise for

the production of bores or similar openings, more particularly through-holes and/or blind holes in automotive engines.

Possible applications hitherto not available for aluminum or alloys thereof are now opened up due to the considerable enhanced strength and hardness, improved ultimate strength, low tolerances and high smoothness as well as an enhanced bonding of galvanized coatings or other materials designed to prevent corrosion and oxidation. as a result of which the versatility of the aluminum or alloys thereof and their long-since accepted advantages are further enhanced.

Further features, advantages and details of the invention read from the following description of preferred embodiments of the invention with reference to the drawing in which:

Fig. 1 is a diagrammatic front view of one embodiment of a device configured in accordance with the invention for surface treatment of a workpiece shown partially sectioned having a round surface, for example, a round or tubular material,

Fig. 2 is a partly sectioned view from above of the device in accordance with the invention as shown in Fig. 1 in the direction of the arrows II-II on a magnified scale,

Fig. 3 is a plan view of the device in accordance with the invention as shown in Fig. 1 in the direction of the arrows III-III on a magnified scale,

Fig. 4 is a plan view of the device in accordance with the invention as shown in Fig. 1 in the direction of the arrows IV-IV on a magnified scale,

Figs. 5A and 5B are each a cross-sectional view through the device in accordance with the invention as shown in Fig. 1

as taken along the line V-V and a diagrammatic plan view of three rolls of the device in accordance with the invention as shown in Fig. 5A each on a magnified scale,

Figs. 6A,6B and 6C are diagrammatic side views of the embodiments of the three rolls of the device in accordance with the invention as shown in Figs. 5A and 5B,each on a magnified scale,

Figs. 7A and 7B are each a partial cross-sectional view through a further embodiment of a device in accordance with the invention as shown in Fig. 1 and a diagrammatic plan view of three rolls of the device in accordance with the invention as shown in Fig. 7A, each on a magnified scale,

Figs. 8A and 8B are each a cross-sectional view through another embodiment of a device in accordance with the invention as shown in Fig. 1 and a diagrammatic plan view on three rolls of the device in accordance with the invention as shown in Fig. 8A, each on a magnified scale,

Figs. 9A and 9B are each a diagrammatic front view of another embodiment of a device in accordance with the invention for surface treatment of a workpiece shown partly sectioned, including at least one flat surface, for example, a workpiece having a square, rectangular or other polygonal cross-section,

Figs. 10A and 10B are each a diagrammatic side and plan view of the rolls of the embodiment of the device configured in accordance with the invention as shown in Fig. 7 corresponding to the detail VIII,

Fig. 11 is respectively a diagrammatic side and plan view of the rolls of the embodiment of the device configured in accordance with the invention as shown in Fig. 7 corresponding to the detail VIII,

Figs. 12A and 12B are each a partly sectioned side view of the device in accordance with the invention as shown in Fig. 7 and a diagrammatic plan view of three rolls of the device in accordance with the invention as shown in Fig. 7, each on a magnified scale,

Figs. 13A, 13B and 13C are diagrammatic illustrations of three example embodiments of possible steps in the method for producing workpieces of optional cross-section in which the device in accordance with the invention is integrated in each case.

It is understood that in the following description of various example embodiments of devices 10 for surface treatment of workpieces 12, for example, in the form of elongated sections having a round surface 14, for example, having a round cross-section in the form of round or tubular material, of workpieces 12', for example of elongated sections, including at least one flat surface, for example, a workpiece having a square, rectangular or other polygonal cross-section and of workpieces 12'' having at least one bore 14'' or similar opening such as a through-hole and/or a blind hole.

Referring now to Figs. 1 to 1C there is illustrated an embodiment of a device 10 in accordance with the invention for the surface treatment of workpieces 12, such as for example, elongated sections having a round surface 14.

Referring now to Figs. 2 to 4 or 5A there is illustrated in part how the device 10 comprises three rolls 16, 16', 16'' arranged parallel to and equispaced about the workpiece 12, i.e. each staggered by 120¡. The three rolls 16, 16', 16'' each comprise the same diameter in the example embodiment of the device 10 as shown in Figs. 2 to 4 or 5A. Accordingly, their longitudinal centerlines 18, 18', 18'' are located on

a common pitch circle 20 and thus each equispaced from the workpiece 12, it being just as possible, however, that the diameter of the three rolls 16, 16', 16'' varies.

The three rolls 16, 16', 16'' are provided at least in part with an outer profile 22, 22' working the surface 14 of the workpiece 12. In the embodiment of the device 10 as shown in Figs. 1 to 6C the rolls 16 and 16' are provided with one such outer profile 22, 22' whereas the roll 16'' is configured non-profiled. It is however just as possible basically to provide, instead of the two rolls 16, 16' only one roll with such an outer profile working the surface 14 of the workpiece 12 (cf Figs. 7A, 7B). It is likewise conceivable that all three rolls 16, 16', 16'' arranged parallel and equispeaced about the workpiece 12 to each other are provided with such an outer profile working the surface 14 of the workpiece 12 (not shown).

The outer profile 22, 22' working the surface 14 of the workpiece 12 of the two rolls 16, 16' is configured in the form of annular beads 24 with recesses 26 arranged inbetween, arranged at an angle α to the longitudinal centerline 18, 18' of the corresponding rolls 16, 16''. Consequently, the beads 24 and recesses 26 of the two rolls 16, 16' run inclined to the longitudinal direction of the rolls 16, 16'. In this arrangement the annular beads 24 protrude beyond the outer diameter of the rolls 16, 16'.

Advantageously, the two rolls 16, 16' are provided at least in part with an outer profile 22, 22' which works the surface 14 of the workpiece 12 in sequence in the opposite direction, i.e. shaping the surface 14 of the workpiece 12 first in one direction and then in the direction opposite thereto.

For this purpose in the embodiment of the device 10 in accordance with the invention as shown in Figs. 1 to 6C the

beads 24 and recesses 26 of the outer profile 22, 22' of the two rolls 16, 16' are arranged inversed to each other, i.e. roughly crosswise. Although the angle α of the outer profile 22 of the roll 16 is identical in magnitude to the angle α' of the outer profile 22' of the roll 16', angles α and α' differ by their sign and are consequently once positive and once negative, or vice-versa. In this arrangement the angles α, α' are in the range 2¡ to 85¡, preferably in the range 2¡ to 60¡ and more particularly in the range 2¡ to 10¡ inclusively.

It is, however, just as possible as an alternative or in addition thereto that the angles α, α' of the pitch of the annular beads 24 and recesses 26 differ from each other in magnitude, so that for example, the angle α is 30¡ and the angle α' is 45¡, whereby any other combination may be provided.

As shown in Fig. 5B the beads 24 or recesses 26 are configured on the roll 16 leading from right-to-left and on the roll 16' from left-to-right. To ensure movement of the workpiece 12 in such a substantially opposite leading position of the beads 24 and recesses 26 of the two adjoining rolls 16, 16', the two rolls 16, 16' can thus be powered in the same direction of rotation.

When, by contrast, however the leading position of the beads 24 and recesses 26 is substantially the same, the two rolls 16, 16' can be powered in the opposite direction of rotation (not shown).

The workpiece 12 in the embodiment of the device 10 in accordance with the invention as shown in Figs. 1 and 5B is moved in the direction of the arrow 28 by the rolls 16, 16', 16'' from right-to-left.

The rolls 16, 16' comprise two ends 30, 32 which as evident from Figs. 5B, 6A and 6B, define the outer profile 22, 22' respectively. In this arrangement the incoming end 30 and outgoing end 32 of the rolls 16, 16' in the direction of movement of the workpiece 12 as indicated by arrow 28 are configured non-profiled or smooth. The incoming end 30 of the rolls 16, 16' comprises a slightly smaller outer diameter for compensating any irregularities of the workpiece 12 to be fed to the outer profile 22, 22' or for exerting a certain straightening function initially, whereas the outgoing end 32 of the rolls 16, 16' comprises a slightly larger diameter to bring the workpiece 12 coming from the region of the outer profile 22, 22' to a constant dimension, namely to the actual or desired design dimension of the workpiece 12 with an extremely smooth surface or low tolerance. By contrast, the roll 16'' is provided full-length with a smooth surface.

Each of the rolls 16, 16', 16'' is in this embodiment configured rotatable about their longitudinal centerlines 18, 18', 18'' as is particularly evident from Fig. 5A. As already mentioned in this arrangement the two rolls 16, 16' having the opposing outer profile 22, 22' can each be powered in the same direction, the roll 16'' having an exclusively smooth surface being powered in the opposite direction of rotation. The direction of rotation of the roll 16'' having the exclusively smooth surface is selectable optional, however.

The rolls 16, 16', 16'' are mounted as shown in Fig. 1 by a drive means 34 and a drive head 36 or by the same driving arrangement. The drive means 34 is provided for rotatating each roll 16, 16', 16'' individually about their longitudinal centerlines 18, 18', 18''. The drive head 36 or similar driving arrangement serve to rotate the rolls 16, 16', 16'' in combination about the workpiece 12.

As shown in Figs. 1, 3 and 6A the incoming end 30 of the rolls 16, 16', 16'' is correspondingly non-rotatively mounted by a section 38, for example, a square section, in a correspondingly formed, substantially snug-fit recess 40 (cf Fig. 3) in the hydraulic drive means 34, whereas the outgoing end 32 of the rolls 16, 16', 16'' is rotatively mounted each via a journal 42 in recesses 43 of the drive head 36 (cf. Fig. 2).

In the embodiment of the device 10 in accordance with the invention as shown in Fig. 1 the drive means 34 is arranged upstream of the drive head 36 or similar driving arrangement in the direction of movement of the workpiece 12 as indicated by the arrow 28. However, it is just as possible to arrange the drive means 34 downstream of the drive head 36 or similar driving arrangement in the direction of movement of the workpiece 12 so that then the now incoming end 30 of the rolls 16, 16', 16'' would be rotatively mounted in the drive head 36 and the then outgoing end 32 of the rolls 16, 16', 16'' would be mounted non-rotatively in the drive means 34.

The drive means 34 and/or drive head 36 or similar driving arrangement of the three rolls 16, 16', 16'' is/are controlled hydraulically or pneumatically in the embodiment of the device 10 in accordance with the invention as shown in Fig. 1. Providing such a drive of the three rolls 16, 16', 16'' permits infinitely variable control in avoiding all and any slip and thus a continuous smooth surface 14 of the workpiece 12 in its being treated. One such hydraulic or pneumatic drive means 34 and/or hydraulically or pneumatically powered drive head 36 can be mounted particularly to advantage by, for example, a sealing arrangement as described in DE 196 10 809 A1. The drive means 34 and/or drive head 36 is/are controllable via a control desk 44.

The drive means 34 comprises a total of three separate drive motors 46 powered preferably hydraulically, each assigned to one end of the rolls 16, 16', 16'', although it is just as possible to power merely the two profiled rolls 16, 16' by means of one such drive motor 46.

The drive head 36 or similar driving arrangement as detailled in Figs. 1 and 2 cooperates with a worm drive 48. To avoid all and any slip the worm drive 48 and thus the drive head 36 are likewise powered hydraulically or pneumatically via a drive motor 50. Via the speed of the worm drive 48, dictating likewise the rotary speed of the drive head 36 and thus the mutual rotary movement of the rolls 16, 16', 16'' about the workpiece 12 to be treated, the feed of the workpiece 12 is dictated likewise by the device 10 in accordance with the invention.

Furthermore, the drive means 34 and the drive head 36 are configured movable relative to each other. For this purpose the drive means 34 is configured longitudinally shiftable via a guide means 52 in the form of a guide rod or the like and a mechanically, electrically, hydraulically or pneumatically actuatable drive element 54 supported by a frame 56 of the device 10. The drive element 54 is preferably configured as a pressure cylinder to thus make it possible to undertake lengthwise compensation of the rolls 16, 16', 16'' differing in length whilst maintaining the interchangeability of the rolls 16, 16', 16'' and thus further enhance the flexibility of the device 10.

To obtain a workpiece 12 having extremely high accuracy or very tight tolerances the drive means 34 and drive head 36 are assigned additional centering means 58. The workpiece 12 moving at very high speed by the device 10 in accordance with the invention as indicated by the arrow 28 is stabilized by any vibrations produced by the surface

treatment in the region of the rolls 16, 16', 16'' being absorbed by the centering means 58.

As indicated merely diagrammatically in Fig. 1 the rolls 16, 16', 16'' are cooled by an internal cooling system. As an alternative or in addition thereto the rolls 16, 16', 16'' may be cooled by an outer cooling bath (not shown) by known ways and means.

It is due to the fact that the workpiece 12 is not worked by any rotary movement - surface treatment of the workpiece 12 instead being achieved by each of the rolls 16, 16', 16'' rotating about their longitudinal centerlines 18, 18', 18'' as well as in combination about the workpiece 12 - that feed rates of up to approximately 100 meters/minute are achievable. Despite this huge improvement in the performance of the device 10 an extremely high accuracy is achievable for the workpiece 12 brought to the finished dimension in the end by the outgoing end 32 of the rolls 16, 16', 16'', thus making accuracy of up to at least approximately 1/10 mm possible, i.e. without any separate subsequent treatment.

Due to the counter- or crosswise orientation of the beads 24 and recesses 26 of the outer profile 22, 22' of the rolls 16, 16' the workpiece 12 is worked by a longitudinal movement without any rotary movement whatsoever.

It is the configuration of the device 10 in accordance with the invention as shown in Fig. 1 that permits achieving a extremely versatile application of the device 10, it thus being possible to make individual use of rolls 16, 16', 16'' differing in length and diameter as well as with a different outer profile 22, 22', i.e. by arranging the beads 24 and recesses 26 differing in pitch and number of beads 24 and recesses 26 as well as different in spacing etc., depending on the dimensions, material properties etc. of the workpiece 12 concerned in each case.

Referring now to Figs. 6A to 6C there is illustrated how the rolls 16, 16', 16'' are configured multi-part, the rolls 16, 16', 16'' thus each comprising a shaft 60 with a stop 62 provided in the region of the section 38. The shaft 60 mounts a sleeve 64 either by the outer profile 22, 22', the incoming end 30 and the outgoing end 32 or by the entirety of the smooth surface. The sleeve 64 is non-rotatively attached to the shaft 60 via a spline 66. In the axial direction the sleeve 64 is locked to the shaft 60 by the stop 62, a ring 68 and a nut 70. It is this multi-part arrangement that facilitates replacing the sleeve 64 when the outer profile 22, 22' of the rolls 16, 16', 16'' is worn or defective. Such a multi-part arrangement had additionally the advantage that the shaft 60 and the sleeve 64 can be worked by different methods of production so that in the end the shaft 60 comprises a high toughness and the sleeve 64 with the outer profile 22, 22' of the rolls 16, 16', 16'' exhibits high hardness and is thus hard wearing.

Referring now to Figs. 7A and 7B there is illustrated how in the embodiment of the device 10 in accordance with the invention only one roll, namely 16''' is provided at least in part with an outer profile 22, 22' for working the surface 14 of the workpiece 12 in sequence in the opposite direction, i.e. the surface 14 of the workpiece 12 first in one direction and then in the direction opposite thereto.

In the device 10 as shown in Figs. 7A and 7B the beads 24 and recesses 26 of the outer profile 22, 22' of the roll 16''' are arranged inverse to each other for this purpose, i.e. roughly crosswise. Although the angle α of the outer profile 22 is identical in magnitude to the angle α' of the outer profile 22' of the roll 16'', angles α and α' differ accordingly by their sign. The roll 16'' rotates about its longitudinal centerline 18'''. The two rolls 16'' are configured non-profiled.

Referring now to Figs. 8A and 8B the example embodiment of the device 10 in accordance with the invention as shown therein differs from the embodiment as shown in Figs. 1 to 6C by the rolls 16, 16', 16'' being used for surface treatment of a surface or in which of a bore 14'' or similar opening, for example, a through-hole and/or blind hole such as the bore in an engine cylinder block of the workpiece 12''. However, it is just as possible to provide only one roll 16''' as shown in Figs. 7A, 7B with an outer profile 22 and/or 22' and/or further profiled rolls 16, 16', for the purpose of surface treatment of the workpiece 12'' or the inner wall of a bore 14'' (not shown).

The rolls 16, 16', 16'' each mounted for example, by a shank 17, 17', 17'' or the like (merely indicated) are supported likewise fully by the inner wall of the bore 14'' of the workpiece 12'', this being all the more of an advantage in that the rolls 16, 16', 16'' are mounted freely supported particularly in surface treatment of a blind hole. It is likewise conceivable to employ only one roll 16. Preferably, however, at least two rolls 16, 16' or 16'' should be put to use, at least one of which should be profiled. These two rolls 16, 16' or 16'' should then be arranged opposite each other, the outer diameter of each of which could then roll on the inner diameter of the bore 14'' to achieve an additional supporting function in surface treatment so that the high production accuracy of the workpiece 12'' after surface treatment is enhanced even further.

Referring now to Figs. 9A to 12B there is illustrated a further embodiment of the device 10 for corresponding surface treatment of workpiece 12' which unlike the workpiece 12 comprises at least one flat surface 14', however. In the example embodiment as shown the workpiece involved is a workpiece 12' having a rectangular cross-

section (cf. more particularly Fig. 12A) whose upper and lower surface 14' is worked likewise.

The device 10 for surface treatment of such workpieces 12' having at least one flat surface 14' is configured in the example embodiment as shown in Figs. 9A and 9B as a press or similar device. The device 10 comprises a mounting device 72 in which a total of four pairs of rolls 74, 74', 74'', 74''' are provided arranged in sequence in the direction of movement of the workpiece 12' as indicated by the arrow 28 and provided at least in part with an outer profile 76, 76', 78, 78' working the surface 14' of the workpiece 12' as will now be detailled in the following.

The rolls 74, 74', 74'', 74''' are rotatively mounted about their longitudinal centerline 80 in a supporting frame 79 which is connected to a head 82 of the mounting device 72. As shown in Fig. 11 the rolls 74, 74', 74'', 74''' are arranged perpendicular to the direction of movement of the workpiece 12' as indicated by the arrow 28, although it is just as possible to arrange this at an angle β inclined thereto (not shown). The angle β in the example embodiment as shown is thus 0¡.

The mounting device 72 cooperates with a supporting means 84 assigned to the mounting device 72 opposite thereto and is provided as a so-called counterbearing for the workpiece 12' in surface treatment thereof. The supporting means 84 in the example embodiment as shown is likewise formed by a total of four pairs of rolls 86, 86', 86'', 86''' correspondingly in number and arrangement to the four pairs of rolls 74, 74', 74'', 74'''. The rolls 86, 86', 86'', 86''' are thus likewise arranged in sequence in the direction of movement of the workpiece 12' as indicated by the arrow 24 and provided at least in part with an outer profile 76, 76', 78, 78' working the surface 14' of the workpiece.

Should surface treatment of the lower surface 14« of the workpiece 12' not be necessary, however, it will be readily understood that in place of the rolls 86', 86'' including an outer profile 76, 76', 78, 78 non-profiled rolls 86, 86''' can likewise be employed. However, it is just as conceivable to configure the supporting means 84 not with the rolls 86, 86', 86'', 86''' but instead, for example, to provide a supporting plate or the like.

The mounting device 72 with the at least one roll 74', 74'' working the upper surface 14' of the workpiece 12'' is movable relative to the supporting means 84 supporting the workpiece 14' to thus ensure treatment of workpieces 12' optional in thickness.

For this purpose the mounting device 72 is movable, i.e. height-adjustable relative to a guide means 88, for example, in the form of guide rods 89 or the like and a mechanically, electrically, hydraulically or pneumatically actuatable drive element 90, the actuatable drive element 90 preferably being configured as a pressure cylinder.

The mounting device 72 and/or the supporting means 84 is/are hydraulically or pneumatically controllable. The pairs of rolls 74, 74''' and 86, 86''' respectively each comprising a smooth surface can be rotatably powered about the longitudinal centerline 80 by means of separate drive motors 92. The drive motors 92 in this arrangement are likewise preferably configured as hydraulic or pneumatic motors so that the feed of the workpiece 12' is optionally, simultaneously but precisely and especially infinitely adjustable. By contrast, the rolls 74'. 74'' and 86'. 86'' respectively are simply freely rotatively mounted in the supporting frame 79 of the mounting device 72.

Even though in the example embodiment of the device 10 as shown in Figs. 9A to 12B only the rolls 74, 74''', 86',

86''' are set in rotation via drive motors 92, it is readily conceivable that as an alternative or in addition any one or all of the rolls 74, 74''' and/or 86, 86''' having an outer profile 76. 76', 78, 78' may be worked by a rotary movement via such drive motors so that the feed of the workpiece 12' is additionally promoted.

Depending on the individual specifications or requirements as to the strength and/or dimensional accuracy of the workpiece 12' this embodiment of the device 10 in accordance with the invention as described by way of an example may be varied optionally, it thus being directly possible to work the upper and/or lower surface 14' of the workpiece 12' simply by a sole roll 74, 74'', 86', 86'' having an outer profile 76. 76', 78, 78' working the surface 14« of the workpiece 12' at least in part. At the same time it is conceivable to elevate the number of rolls 74, 74'', 86', 86'' having an outer profile 76. 76', 78, 78'.

Referring now to Figs. 10A, 11, 12A and 12B there is illustrated clearly how the rolls 74, 74'', 86', 86'' comprise the outer profile 76, 76', 78, 78' working the surface 14' of the workpiece 12' at least in part in the form of annular beads 94 and recesses 96, whereby each of the rolls 76, 76', 78, 78' is adapted to the other.

Where the rolls 74', 86' are concerned the annular beads 94 and recesses 96 are arranged perpendicular to the longitudinal centerline 80 of the rolls 74', 86'. Consequently, the annular beads 94 and recesses 96 of the rolls 76', 86' are oriented parallel in the direction of movement of the workpiece 12' as indicated by the arrow 28.

Where the rolls 74'', 86'' are concerned the annular beads 94 and recesses 96 are arranged at an angle α or α' to the longitudinal centerline 80 of the rolls 74'', 86'' in accordance with the example embodiment as shown in Fig. 1.

Consequently, the annular beads 94 and recesses 96 are provided pitched or inclined to the direction of movement of the workpiece 12' as indicated by the arrow 28, whereby the beads 94 and recesses 96 are arranged opposing, i.e. crosswise.

Preferably the rolls 74', 86' or 74'', 86'' having the outer profile 76, 76', 78, 78' are arranged in pairs in sequence in the direction of movement of the workpiece 12' as indicated by the arrow 28 such that the surface 14' of the workpiece 12' is worked in sequence in the opposite direction. The surface 14' of the workpiece 12' is consequently shaped roughly transversely to the direction of movement of the workpiece 12' as indicated by the arrow 28 once in the one direction and then back in the opposite direction.

This may be done in the case of the two rolls 74' and 86' respectively arranged downstream of each other with the beads 94 and recesses 96 arranged perpendicular to the longitudinal centerline 80 thereof in that the two rolls 74' and 86' respectively and/or the annular beads 94 and recesses 96 are staggered axially to each other.

Where the two rolls 74'' and 86'' respectively arranged downstream of each other are concerned with the annular beads 94 and recesses 96 at an angle α or α' to the longitudinal centerline 80, two possibilities exist for such a reciprocating shaping of the surface 14' of the workpiece 12'. One possibility is to drive the two rolls 74'', 86'' in the same direction of rotation corresponding to the example embodiment as shown in Figs. 10A and 9 for the substantially opposing lead position of the beads 94 and recesses 96. The other possibility is to drive the two rolls 74'' or 86'' in the opposite direction of rotation for the same lead position of the beads 94 and recesses 96 (not shown). Both embodiments are the same in their effect and function.

Referring now to Figs. 10A, 11 and 12B there is illustrated in conclusion how the pairs of rolls 74, 74''' and rolls 86, 86''' respectively comprise a smooth surface. The rolls 74, 74''' and rolls 86, 86''' are arranged upstream and/or downstream of the rolls 74', 74'' and 86', 86'' respectively having the corresponding outer profile 76, 76' and 78, 78' respectively in the direction of movement of the workpiece 12' as indicated by the arrow 28. The rolls 70 and 86 incoming in the direction of movement are configured, however, with a slightly smaller outer diameter whereas the outgoing rolls 70''' and 86''' respectively are configured in the direction of movement with a slightly larger outer diameter.

It is directly possible to provide only the rolls 74', 86' or 74'', 86'' and/or to combine the rolls 74', 86' and/or 74'', 86'' instead of or with each other in any other sequence to thus make it possible, for example, to arrange a roll 74' having the outer profile 76, a roll 74'' having the outer profile 78, a roll 74'' having the outer profile 78' and a roll 74' having the outer profile 76' in series or in any other combination.

As illustrated especially in Fig. 12A the rolls 74', 86' assigned to each other may be configured with outer profiles 76 and 76' respectively etc. different from each other, the same applying correspondingly to the rolls 74'', 86'',

Referring now to Figs. 13A and 13B there is illustrated the steps in the method in which the surface treatment in accordance with the invention and the corresponding device in accordance with the invention is integrated.

As evident from Fig. 13A the workpiece 12, 12' is extruded preferably from aluminum in a press 98 and then worked by cooling in a bath 100 and then straightened in a

straightening bench 102 before then being surface treated in a device 10 in accordance with the invention, after which it is shaped in a shaping bench 104 and finally cut to length in a cutting means 106.

The method as shown in Fig. 13B differs from that as shown in Fig. 13A only by the workpiece 12, 12' after surface treatment in the device 10 in accordance with the invention being directly coiled on a reel 108. This is possible for the first time by the device 10 in accordance with the invention since the workpiece 12, 12' is worked by no rotation in itself, it instead being moved only straight in the longitudinal direction as indicated by the arrow 28.

The method as shown in Fig. 13C differs in turn from that as shown in Fig. 13B merely by a device 110 for coating and/or anodizing and/or galvanizing and/or pickling the workpiece 12, 12' with metals such as chromium, copper, etc, paints, e.g. anodizing paints resistant to abrasion, or plastics. The device 110 is arranged between the device 10 in accordance with the invention for surface treatment and the reel 108.

The method and device 10 in accordance with the invention are particularly suitable for mass production of elongated sections, such as for example, automotive headrest brackets or the like made preferably of aluminum or alloys thereof. More particularly the headrests produced as such are characterized by an especially high strength, on the one hand, and, on the other, by being pliant to a certain degree so that head injuries of the vehicle occupants can be avoided when the vehicle is involved in a head-on collision.

It is understood that the method and the corresponding devices in accordance with the invention are not restricted to the embodiments as described above by way of example, it thus being conceivable that also the side surfaces are

worked correspondingly to the upper or lower surface of the workpiece in the example embodiment of the device in accordance with the invention as shown in Figs. 9A to 12B. For this purpose this would merely require arranging at least one roll in each case having an outer profile roughly perpendicular to the rolls as described. In accordance therewith it is just as possible to configure the workpiece to be treated in any other metal or metal alloy commercially available, the same applying to any coatings to be provided of the already treated workpiece or of a surface or bore etc which may likewise be configured optionally, consequently of metal or a metal alloy and/or paint and/or plastics material.